verse bars outlined in black and are only 4 mm in length. Neither agent is expected to effect complete control of *M. faya* because of faya's exceptionally invasive traits such as its ability to fix nitrogen, rapid growth rate, and high rate of seed production (Vitousek & Walker 1989).

LITERATURE CITED

DAVIS, C. J. & N. L. H. KRAUSS. 1962. Recent developments in the biological control of weed pests in Hawaii. Proc. Haw. Entomol. Soc. 18:65–67.

DESCHKA, G. 1976. Lithocolletidae von Madeira (Lepidoptera). Entomol. Ber. 36:90–96.

GARDNER, D. E., G. P. MARKIN & C. S. HODGES, JR. 1988. Survey for potential control agents for *Myrica faya* in the Azores and Madeira. Technical Report 63. Cooperative National Park Resources Studies Unit, Dept. Botany, Univ. Hawaii, Honolulu, Hawaii. 18 pp.

JULIEN, M. H. (ED). 1992. Biological control of weeds: a world catalogue of agents and their target weeds. CAB International. 186 pp.

KLIMESCH, L. V. J. 1970. *Caloptilia schinella* Wlsghm. (1907) (=*C. terebinthiella* Chret. 1910) (Lep., Lithocolletidae). Nachricht. Bayerisc. Entomol. 19(5):84–89.

MARKIN, G. P. 1991. Insect survey of potential biological control agents of *Myrica faya* in the Azores and Madeira Islands, Portugal, 1988. Technical Report 75. Cooperative National Park Resources Studies Unit, Dept. Botany, Univ. Hawaii, Honolulu, Hawaii. 26 pp.

MARKIN, G. P., R. F. NAGATA & D. E. GARDNER. 1991. Biological control of introduced weeds of native Hawaiian forests. *In* Conrad, C. E. & L. A. Newell, (Tech. Coordinators), Proceedings of the session on tropical forestry for people of the Pacific, XVII Pacific Science Congress (27–28 May 1991) Honolulu, Hawaii. Gen. Tech. Rep. PSW-GTR-129, Albany, California: Pacific Southwest Research Station, Forest Service, U. S. Department of Agriculture.

TAKHTAJAN, A. L. 1980. Outline of the classification of flowering plants (Magnoliophyta). Bot. Rev. 46:225–359.

TAYLOR, D. & G. P. MARKIN. 1992. Release of a defoliator moth as a biological control agent of firetree in the park. Unpubl. environmental assessment for release into Hawaii Volcanoes National Park, Hawaii. 23 pp.

VITOUSEK, P. M. & L. R. WALKER. 1989. Biological invasion by *Myrica faya* in Hawaii: plant demography, nitrogen fixation, and ecosystem effects. Ecol. Monogr. 59: 247–265.

WALSINGHAM, L. 1907. Microlepidoptera of Tenerife. Proc. Zool. Soc. London, pp. 982–983.

ROSEMARY LEEN AND GEORGE MARKIN, *U. S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, P. O. Box 236, Volcano, Hawaii 96785, USA.*

Received for publication 20 March 1995; revised and accepted 7 January 1996.

Journal of the Lepidopterists' Society
50(4), 1996, 350–353

SEXUAL DIMORPHISM IN THE COCOON COLOR OF *BOMBYX MORI* (BOMBYCIDAE)

Additional key words: pupal color, voltinism.

The mulberry silkworm, *Bombyx mori* L., is one of the most commercially exploited lepidopteran species. Hybrids between commercial silkworm strains are reared to produce

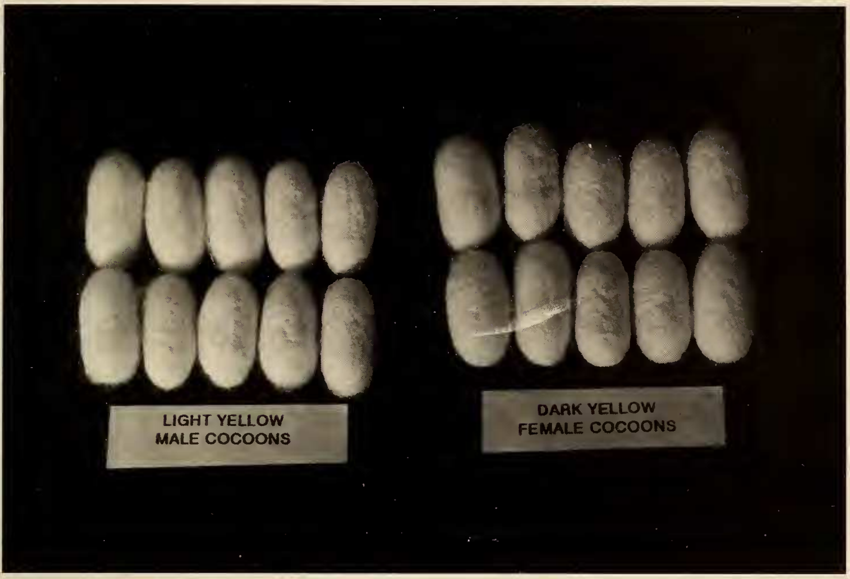

FIG. 1. Sexual dimorphism in cocoon color in *Bombyx mori*.

cocoons for raw silk production. In the production of hybrids, sex separation is necessary to prevent free mating between siblings. In the silkworm industry in India, sex separation is based on the imaginal spot on the lower segment of pupae, which provides reasonably reliable determinations but requires considerable labor (silkworm larvae have Herold's imaginal bud in males and Ishiwada's gland in females on the ventral side of the 8th and 9th abdominal segments; similar visible external characters are known in Saturniidae; see Miller et al. 1977, Miller & Machotka 1980). Pupal sexing also requires cutting open cocoons to confirm sex. In the preparation of silkworm hybrids, this method of sex separation becomes expensive when reciprocal crosses are not desired.

Several studies have been conducted on sex determination in parental races at different developmental stages in silkworms (Tazima 1978a, 1978b, Abadzhieva & Tanev 1987). Sengupta (1968) reported sex-limited characters of larval markings in a Russian silkworm race. Krishnaswami et al. (1981) observed sexual dimorphism in cocoon color in Hosa Mysore, a multivoltine silkworm race. Nagaraj and Rao (1987) succeeded in introducing sex-limited cocoon color into bivoltine silkworm races CC1 and NB4D2. However, these characters could not be commercially exploited owing to the low survivorship and stability in these races.

In the present study, we attempted to fix a breeding line from a back cross of (Mysore local × N4) × Mysore Local with sexual dimorphism in cocoon color to facilitate the process of hybrid silkworm seed production in commercial grainages with minimal wastage. Segregation of lines was made after the F3 generation. In one of the sub-lines cocoon color was found to exhibit sexual dimorphism. Studies of the sexual dimorphism began with random cocoon sampling from five batches. Light yellow and dark yellow colored cocoons were separated visually into groups. These cocoons were then cut open and sexed on the basis of pupal markings. This attempt to classify coccons was repeated four times.

In an isolated sub-line from the three way cross of (Mysore local × N4) × Mysore Local, sexual dimorphism in cocoon color was observed in the F12 generation (Fig. 1; male cocoons are light yellow in color, whereas female cocoons are dark yellow). In visually selected light yellow cocoons 96.5% were male and in dark yellow cocoons 92.5% were fe-

TABLE 1. Results of attempts to segregate *Bombyx mori* cocoons by sex using cocoon color.

Cocoon Color	Sample Size	Replications	Percent Male	Percent Female
light yellow	400	4	96.5 ± 4.7	3.5 ± 4.7
dark yellow	400	4	7.5 ± 9.6	92.5 ± 9.6

male (Table 1). The female cocoons were more elongate, less flossy and slightly larger than the male cocoons. Slightly oval, spindle-shaped cocoons were common in both sexes.

Tazima (1978a) has explained the phenomenon of difference in cocoon color between sexes and reported that cocoon color in most of the colored cocoon producing silkworm races is directly related to hemolymph color, except in some European races where the expression of cocoon color is influenced by an inhibitor gene. The presence of the yellow blood gene (Y) in silkworms is responsible for yellow color in cocoons. The allele +C inhibits transmission of pigments into any part of the middle silk gland, resulting in production of white cocoons in some silkworm genotypes. Presence of Y and +C alleles in tandem is stated to be responsible for intermediate color in cocoons and polymorphism in hemolymph color (Tazima 1978a; Ford 1975 reported that hemolymph color is always darker in females than in males of *Choristoneura pinus* (Tortricidae)).

It is interesting to note that the colored cocoon producing races of *Bombyx mori* in India, such as Nistari (golden yellow) and Mysore Local (greenish yellow), do not exhibit clear sexual dimorphism in cocoon color. However, use of these in the formation of new races through hybridization resulted in sexual dimorphism in the isolated sub-lines (Krishnaswamy et al. 1981, Nagaraj & Rao 1987, Singh et al. 1992). Similarly, in the present study, two parental races (Mysore Local multivoltine race with greenish yellow cocoon, and N4 bivoltine race with white cocoon) were combined in a three way cross to obtain a breeding line with sexual dimorphism in cocoon color. The relative importance of genetic and environmental factors in the expression of sexual dimorphism in cocoon color could not be determined in the present study. Further work is ongoing to obtain detailed information on sexual dimorphism and its relation to climatic and other ecological conditions.

We thank S. Sekar, stenographer of the Regional Sericultural Research Station, Coonoor for typing this manuscript and to the technical staff who assisted in the completion of this study.

LITERATURE CITED

ABADZHIEVA, R. & G. TANEV. 1987. A genetic marker for sex in the silkworm. Genet. Sel. 19:535–538.

FORD, E. B. 1975. Ecological genetics. Chapman & Hall, London. 173 pp.

KRISHNASWAMI, S., M. N. S. IYENGAR & S. N. MALAVATHY. 1981. Cocoon colour as an indication of sex in Hosa Mysore, an evolved silkworm, *Bombyx mori* L. Proc. Seric. Symp. Semi. 18–20.

MILLER, T. A., W. J. COOPER & J. W. HIGHFILL. 1977. Determination of sex in four species of giant silkworm moth larvae (Saturniidae) J. Lepid. Soc. 31:144–146.

MILLER, T. A. & S. V. MACHOTKA. 1980. Sex-related morphological characters in larvae of *Hyalophora gloveri* and *Antheraea polyphemus* (Saturniidae). J. Lepid. Soc. 34:69–73.

NAGARAJ, C. S. & R. M. RAO. 1987. Newsletter, Central Sericultural Research & Training Institute, Mysore. 2:3.

SENGUPTA, K. 1968. Sex linked (sex limited) characters in two races of silkworm *Bombyx mori* L. maintained by the Central Silkworm Seed Station, Srinagar and the method for its transfer to other races for commercial exploitation. Indian J. Sericul. 7:79–85.

SINGH, K., T. P. S. CHAUHAN & MEERA VERMA. 1992. Sexual dimorphism in cocoon colour of some multivoltine and bivoltine silkworm (*Bombyx mori* L.) ecoraces. Indian J. Entomol. 54:365–367.

TAZIMA, Y. 1978a. The silkworm – an important laboratory tool. Kodamsha Ltd., Japan. 307 pp.
———. 1978b. The silkworm egg. Central Silk Board, India. 49 pp.

V. THIAGARAJAN, T. P. S. CHAUHAN AND E. RAJALAKSHMI, *Regional Sericultural Research Station, Central Silk Board, Coonoor-643 101, Tamil Nadu, India.*

Received for publication 30 June 1994; revised and accepted 7 January 1996.